The diet of the badger *Meles meles* (Mustelidae, Carnivora) on the Apennines (Central Italy)

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Meles meles, régime alimentaire, habitat de montagne, Italie.

Despite the feeding ecology of badger has been widely investigated throughout Europe, the food habits of populations living in mountainous environments are generally poorly known. Lucherini & Crema (1995) and Deflorian *et al.* (2001) carried out in the Italian Alps the only studies based on scat analysis dealing with the annual diet of the badger at the limit of the altitudinal range of the species.

Several studies revealed that the diet of a predator can change in composition and diversity in relation to different habitats (Fedriani 1996 for red fox; Genovesi *et al.* 1996 for stone marten). Mouches (1981), Kruuk & Parish (1981), Lambert (1990) and Martin *et al.* (1995) studied the inter-habitat differences in the badger diet, mostly in relation to earthworm consumption. At present, information about spatial variation in badger feeding habits remain scarce.

The aim of the present study is twofold: 1) to describe the diet of the badger on the Apennines, at the limit of the altitudinal range of the species, 2) to compare dietary differences in relation to different habitats.

This study was carried out in Abruzzo Lazio and Molise National Park (41°45'N, 15°55'E), hereafter PNALM. The study area covers approximately 76 km^2 and ranges from 1000 to over 2000 m a.s.l. The landscape is mountainous and shows several karst features due to the widespread calcareous rocky formations. The climate is Mediterranean (Montelucci 1971); annual average rainfall is 1314 mm (minimum in August, 41 mm; maximum in November, 258 mm);

winter is characterised by 4-5 months of permanent snow cover; annual mean temperature is 9 °C (minimum in January, 0.9 °C; maximum in August, 17.5 °C) (Conti 1995). The calcareous and permeable substratum can make the soil quite dry in summer (Bazzichelli & Furnari 1971). Woodlands cover most of the study area (48%); oaks *Quercus* sp. mixed with common hazel *Corylus avellana*, hop hornbeam *Ostrya carpinifolia*, and maples *Acer* sp. occur at lower altitudes, while beech *Fagus sylvatica* mixed with sycamore *Acer pseudoplatanus*, rowan *Sorbus aucuparia* and whitebeam *S. aria* at higher altitudes; buckthorns *Rhamnus* sp. occur in glades and ecotonal zones of the forest. Open areas are also widespread (meadows and fallow fields 28.6%, cultivated fields 3%, and pastures 8%) and are scarcely interspersed with woodlands; they are characterised by several shrub and tree species, with a prevalence of cornelian cherry *Cornus mas*, dogwood *C. sanguinea*, apples *Malus* sp., common and midland hawthorn *Crataegus monogyna* and *C. laevigata*, cherries *Prunus* sp., wild roses *Rosa* sp., blackberries *Rubus* sp., and junipers *Juniperus* sp. No rubbish dumps occur in the study area.

The study was based on faecal analysis. Between March 1997 and May 1998, 109 fresh scats were collected monthly from latrines or temporary defecation sites (TDS, Roper *et al*. 1986) and then stored frozen. Few scats were collected in winter (n = 11), when the harsh climate probably limited the badger external activity. Faeces were analysed following the procedures of Kruuk & Parish (1981) and Bradbury (1977). Prey items were separated and identified by macroscopical and microscopical analyses with the help of our reference collections and specific keys (Pucek 1981; Teerink 1991; De Marinis & Agnelli 1993). They were classified in seven food categories: mammals, birds and reptiles, insects, insect larvae, earthworms, other invertebrates and fruits. Vegetable matter (leaves, grasses and mosses) were not included in the analyses as they could be swallowed by chance during feeding and bedding activity (Neal & Cheeseman 1996). The number of items was estimated counting: legs and elytra, in few cases head capsules and mandibles, for insects; head capsules for larvae; *opercula* or shell apexes for snails and slugs; gizzard rings for earthworms; teeth and mandibles for mammals and reptiles; seeds and stem attachments for fruits. The average number of seeds per fruit was estimated with the help of our reference collection or was found in literature (Debussche 1988).

Data were expressed as: frequency of occurrence % O (number of occurrences of each food category / total number of faeces × 100); relative frequency of occurrence % R (number of items of a given food category / total number of items × 100); percentage of estimated volume of each food category whenever it was eaten % EV; and volume in the total diet % VT (% O × % EV) (Kruuk & Parish 1981).

To study the inter-habitat variability in the diet we used those scats collected in two sub-areas predominantly characterized by wooded (n = 43) or open (n = 37) habitats. To better analyse the diet variation between habitats, prey items were classified in the following food categories: rodents, other mammals, birds and reptiles, beetles, orthopters, insect larvae, other invertebrates, tree and shrub fruits. The consumption of each feeding category was compared by χ^2 tests on contingency tables based on frequency of occurrence. The trophic niche breadth was assessed by Levins' measure B, and Levins' standardized measure B_{sta} while niche overlap was assessed by Horn's index of similarity (Krebs 1989). These parameters were calculated using the volume in the total diet.

Forty-five taxa were identified revealing a wide trophic spectrum. Fruits and insects represented the bulk of the diet (72% VT).

Fruits occurred in more than half the sample (54.1% O) with the highest percentage of volume (42.7% VT). Fleshy fruits represented 91% of the fruit remains. Drupes and pomes were the most common type of fruit eaten by badgers (58.5% and 32.3%, respectively). Large fruits (diameter > 10 mm) falling to the ground after ripening, were mostly consumed. Red, black and variously coloured fruits were equally recovered.

Some scats contained up to 5 species of different fleshy fruited plants, but most of the scats (87%) contained seeds from 1 to 2 plant species. Only a small proportion (1%) of the 4292 seeds ingested by badgers was damaged. Rosaceae were the most common fruits in the diet of badger (Table 1).

Insects occurred in 80.7% of the faeces corresponding to 25.8% of the total volume. They were mostly Coleoptera (Carabidae), while Orthoptera (Acrididae and Gryllidae) were the second important food resource; Geotrupidae, Melolontidae and Tettigoniidae were of secondary importance; other insects were eaten only occasionally (Table 1). Insect larvae (31.2% O, 3.5% VT) were exclusively represented by Coleoptera (Carabidae and Scarabeidae). Badgers find them mainly digging the ground surface with forelegs (Pigozzi 1989); signs of this foraging behaviour were often recorded around setts.

Mammals occurred in 44% of faeces accounting for 23.9% of the total volume. Remains of 75 mammals were recovered, most of them were Rodents (Table 1). Field mice (*Apodemus* sp.) and Savi's pine voles (*Microtus savii*) were the most common preys. Insectivores were scarcely represented. Fat dormice, hares, red deer and wild boar (piglets) were likely eaten as carrion.

Birds and reptiles represented only 1.7% in volume of the total diet. Remains of birds were recovered in ten faeces and probably owned to unfledged individuals, while Reptiles (*Podarcis* sp.) just in a single scat. Earthworms occurred only in three scats collected in winter (0.6% VT). Other invertebrates (17.4% O, 1.8% VT) were mostly represented by snails and slugs.

Niche breadth of the badger in PNALM was $B = 3.07$ or $B_{sta} = 0.34$.

In wooded habitats the diet of the badger was based on fruits (49.8% VT) and insects (36.2% VT), while in open habitats on insects (35.7% VT) and mammals (42.8% VT) (Fig. 1).

The exploitation of the tree fruits was higher in wooded habitats ($\chi^2 = 10.94$, $P < 0.001$), while no significant differences were recorded in the consumption of shrub fruits (Table 2). Some fruit species were found exclusively in scats collected in open (*Prunus* sp. and *Cornus* sp.) or in

TABLE 1. — Diet of the badger in PNALM referred to the key food categories (fruits, insects and mammals). % O = frequency of occurrence. Number of scats = 109.

		% O
FRUITS	ROSACEAE	44.9
	Pyrus piraster	18.3
	Prunus sp.	10.1
	Malus sp.	9.2
	Sorbus sp.	9.2
	Rubus sp.	4.6
	Crataegus sp.	2.7
	Amelanchier ovalis	1.8
	FAGACEAE	13.8
	Quercus sp.	11.9
	Fagus sylvatica	1.8
	RHAMNACEAE *Rhamnus* sp	4.6
	CORNACEAE *Cornus* sp.	4.6
	GROSSULARIACEAE *Ribes* sp.	3.7
	CORYLACEAE *Corylus avellana*	1.8
	PAPILIONACEAE	0.9
INSECTS	COLEOPTERA	76.1
	Carabidae	68.8
	Melolontidae	22.0
	Geotrupidae	14.7
	Curculionidae	7.3
	Tenebrionidae	5.5
	Scarabaeidae	2.7
	Staphilinidae	1.8
	Elateridae	1.8
	Aphodidae	0.9
	Silphidae	0.9
	Coleoptera non identified	6.4
	ORTHOPTERA	56.0
	Acrididae	33.0
	Gryllidae	30.3
	Tettigoniidae	12.8
	HYMENOPTERA	1.8
	Formicidae	0.9
	Apidae	0.9
	DERMAPTERA	7.3
	HEMIPTERA	0.9
	INSECTS NON IDENTIFIED	3.7
MAMMALS	RODENTIA	22.9
	Microtus savii	13.8
	Clethrionomys glareolus	3.7
	Arvicolinae non identified	1.8
	Apodemus sp.	7.3
	Glis glis	2.7
	Rodentia non identified	2.7
	INSECTIVORA	2.7
	Talpa sp.	1.8
	Crocidura sp.	0.9
	LAGOMORPHA	5.5
	Lepus europaeus	2.7
	Lepus sp.	2.7
	UNGULATA	10.1
	Cervus elaphus	6.4
	Sus scrofa	3.7
	MAMMALS NON IDENTIFIED	5.5

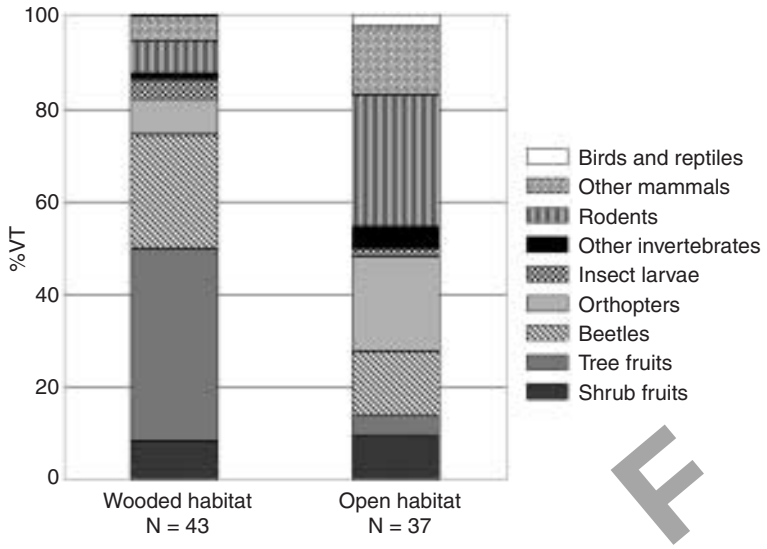

FIG. 1. — Inter-habitat variability in the badger diet in PNALM. % VT = volume in the total diet, N = number of scats.

TABLE 2. — Fruit, insect and mammal composition in the badger diet in PNALM in wooded (W) and open (O) habitats. % O = frequency of occurrence, % R = relative frequency of occurrence. Number of scats: 43 (W), 37 (O). Number of fruits: 707 (W), 660 (O); insects: 1247 (W), 513 (O); and mammals: 24 (W), 42 (O).

	% O		% R	
	W	O	W	O
FRUITS	62.8	43.2	–	–
TREE FRUITS	58.1	21.6	54.6	8.9
Quercus sp.	20.9	2.7	3.4	0.1
Fagus sylvatica	4.7	–	14.4	–
Pyrus piraster	32.6	8.1	6.4	1.5
Malus sp.	14.0	5.4	1.0	0.3
Sorbus sp.	11.6	8.1	22.9	7.0
Amelanchier ovalis	4.7	–	6.5	–
SHRUB FRUITS	18.6	27.0	45.4	91.1
Crataegus sp.	7.0	–	13.2	–
Rhamnus sp.	7.0	2.7	31.1	2.0
Cornus sp.	–	8.1	–	41.8
Rubus sp.	4.6	2.7	0.4	5.3
Prunus sp.	–	18.9	–	42.0
Ribes sp.	4.6	–	0.6	–
INSECTS	72.1	81.1	–	–
COLEOPTERA	48.8	51.3	82.8	55.2
Carabidae	58.1	56.8	77.6	40.7
Melolontidae	18.6	29.7	1.7	10.5
Geotrupidae	18.6	13.5	3.5	3.9
ORTHOPTERA	30.2	54.0	14.4	38.0
Acrididae	30.2	32.4	11.1	11.1
Gryllidae	18.6	48.6	2.6	24.0
Tettogoniidae	7.0	16.2	0.7	2.9
MAMMALS	39.5	62.2	–	–
RODENTS	16.2	40.5	37.5	83.3
OTHERS	32.6	21.6	62.5	16.7

wooded habitats (*Fagus sylvatica*, *Crataegus* sp. and *Amelanchier ovalis*), according to the different distribution of these fruited plant species (Table 2).

The mean number of insects *per* scat was 29 and 13 in wooded and open habitats, respectively. Coleoptera were equally exploited in open and wooded habitats while Orthoptera ($\chi^2 = 4.66$, $p < 0,05$) were more frequently preyed on in open areas (Table 2). In terms of relative abundance, Coleoptera largely predominated in woods while Orthoptera in open habitats (Table 2). Other invertebrates were frequently found in the scats collected in woods (34.9% O) and were mostly represented by slugs ($\chi^2 = 8.18$, $p < 0.01$). Among mammals, insectivores occurred only in scats collected in wooded habitats while most of rodents (80.5%) was found in those collected in open habitats ($\chi^2 = 7.26$, $p < 0.01$) (Table 2). No inter-habitat difference was recorded in carrion consumption. Remains of two or more (up to seven) mammalian preys per scat were found in 21.7% of the open habitat sample, whilst 5.9% of the wooded habitat sample (just one scat) included remains of more than one prey. Birds, reptiles and insect larvae were scarcely consumed in both habitats.

In open habitats the niche breadth was B = 5.71 (B_{sta} = 0.59), while in wooded one was 3.95 (Bsta = 0.33). The degree of overlap between the two habitats, as showed by Horn index, was 0.76. Fruits and insects constituted the bulk of the diet (72% VT) of the badger in PNALM. Fruits and insects are clumped and abundant feeding resources and badgers exploit them profitably. Energy costs of feeding are mainly related to mobility costs depending on food dispersion. Therefore, clumped and abundant food resources are expected to be preferred (MacDonald 1983; Stephens & Krebs 1986; Carr & MacDonald 1986). Moreover this kind of diet seems to be well balanced nutritionally. Fruits provide especially carbohydrates while proteins and lipids are provided by insects. The gastro-intestinal anatomy of the badger, with a relatively long small intestine, is able to process with reasonable efficiency also fleshy fruits containing short chain sugars and could explain its frugivorous habits (Stark *et al.* 1987).

As already reported for a Mediterranean coastal habitat (Pigozzi 1992), the badger seems to behave as seed disperser of fleshy fruited plants also in mountainous habitats. Infact, only a small proportion of seeds (1%) was damaged or destroyed after fruit ingestion and the extent of seed mixing in the scats was relatively small (< 5% of the faecal samples had seeds from 3 plant species) and hence the competition among germinating seeds is expected to be small too.

Fruits and/or insects constitute the trophic basis for several Italian badger populations in different ecosystems (e.g. Ciampalini & Lovari 1985 for coastal habitat; Melis *et al.* 2002 for hilly habitat; Biancardi *et al.* 1995 for Prealps; Deflorian *et al* 2001 for Alps). It seems to be a clear trend in Europe towards an higher consumption of these food categories at lower latitude (Goszczyński *et al.* 2000). The abundance and diversity of fleshy-fruited plants and insect species characterizing the Mediterranean region (Schall & Pianka 1979; Rosenzweig 1992) can explain this geographic variation in the badger diet.

Earthworms were not an important food category in the badger diet in our study area. However, the method adopted may have underestimated the volume of earthworms in the diet. The presence of earthworms on the surface is mainly affected by temperature, windspeed, soil type and humidity (MacDonald 1980; Kruuk & Parish 1981; Lambert 1990). In PNALM these factors could negatively influence the earthworm availability, making this resource not constant and large enough for badgers nutritional requirements. The role of earthworms in the badger diet change with latitude, decreasing from North to Southern Europe (Goszczyński *et al.* 2000). In Italy earthworms represent a secondary feeding resource and their contribution to the diet is highly seasonal. In Alps and Prealps earthworms range from 8% to 14% of the volume in the total diet, while in the hilly and coastal areas of Central Italy from 0.4% to 2.5%. Only in the Po Plain earthworms are a staple food in the diet (Canova & Rosa 1993; Prigioni *et al.* 2002) and are consumed in a great amount (about 50% of the volume in the diet) in any season (Prigioni *et al.* 1988). The feeding ecology of the badger populations inhabiting the agricultural lands of Northern Italy seems to be similar to that of the populations living in Central and Northern Europe.

The results of the present study also described an inter-habitat variability in the badger diet in terms of dominant food categories and their composition. Fruits and insects were the key food resources in woods, insects and small mammals, mainly rodents, in open habitats. Although this study does not provide data on resource availability, this dietary variation is presumably related to the local abundance of the feeding resources. Fleshy-fruited plants were scarcely represented in open areas, while they were more abundant in woods in terms of number of individuals and species. The badger can always find in woods a great amount of fruits from summer to winter, in relation to different ripening period of each species. On the other hand, rodents, especially voles, are likely more abundant in open areas than in woods (D. Russo pers. com.). Fruit, mammal and insect composition greatly varied between habitats in relation to different ecologi-

cal distribution of the prey species. For instance, *Gryllus campestris* mainly occurs in pastures, while most of Carabidae species inhabit forested habitats and ecotones (Vigna Taglianti 1995; Migliaccio pers. com.). The diet of the badgers inhabiting woods and open areas seems clearly replicate this ecological distribution.

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